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CURRENT SUBSIDENCE RESEARCH IN WEST GERMANY AND GREAT BRITAIN AND ITS APPLICATION TO THE SYDNEY COALFIELD, NOVA SCOTIA

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February 1984

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33 pp

ENERGY RESEARCH PROGRAM
COAL RESEARCH LABORATORIES
DIVISION REPORT ERP/CRL 84-9(TR)

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CURRENT SUBSIDENCE RESEARCH IN WEST GERMANY AND GREAT BRITAIN AND ITS APPLICATION TO THE SYDNEY COALFIELD, NOVA SCOTIA

by

T. R. C. Aston*

SUMMARY

In November 1983, a visit was made to West Germany and Great Britain in order to discuss the current status of subsidence research in both countries and assess its application to the current programme being undertaken in the Sydney Coalfield, Nova Scotia. Topics discussed in the report include data collection techniques, the use of prediction models requiring verification with field data, the increasing use of computerized methods for subsidence prediction and the influence of geological conditions on the final subsidence profile. The importance of effectively sealing offshore exploration boreholes and the benefits of understanding the in situ permeability changes occurring around longwall panels are also examined.

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RECHERCHE ACTUELLEMENT MENÉE EN ALLEMAGNE DE L'OUEST ET EN GRANDE-BRETAGNE SUR LES AFFAISSEMENTS DE SOL ET SON APPLICATION AU GISEMENT HOUILLER DE SYDNEY, EN NOUVELLE-ÉCOSSE

par

T. R. C. Aston*

SOMMAIRE

En novembre 1983, une visite a été organisée en Allemagne de l'Ouest et en Grande-Bretagne afin de se rendre compte sur place de la progression de la recherche qui y était menée sur les affaissements de sol et d'évaluer ses possibilités d'application au programme entrepris au gisement houiller de Sydney, en Nouvelle-Écosse. Le rapport traite notamment des techniques de capture des données, du recours à la modélisation dont les résultats sont par la suite vérifiés au moyen de données réelles, le recours de plus en plus grand à l'informatique pour prédire les affaissements et l'influence de la géologie du sol sur le profil d'affaissement. Il porte aussi sur l'importance de bien boucher les trous de sonde d'exploration au large des côtes et des avantages qu'il y a à mieux saisir les mutations de la perméabilité du sol le long des murs de longue tranche.

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CONTENTS

	Page
SUMMARY	i
SOMMAIRE	ii
INTRODUCTION	1
SUBSIDENCE RESEARCH IN THE RUHR COALFIELD, WEST GERMANY	2
Introduction	2
Subsidence Prediction	3
Subsidence Monitoring in the Ruhr Coalfield	3
A Case Study - Nordstern Colliery	6
Subsidence Prediction - Ruhrkohle AG	9
SUBSIDENCE RESEARCH IN GREAT BRITAIN	9
1. NCB North-East Area HQ, Gateshead	9
2. NCB Mining Department HQ, Doncaster	13
3. Nottingham University, Mining Department	14
THE EFFECTIVE SEALING OF OFFSHORE EXPLORATION BOREHOLES	15
IN SITU STRATA PERMEABILITY CHANGES DUE TO MINING	15
DISCUSSION	16
CONCLUSION	17
ACKNOWLEDGEMENTS	18
REFERENCES	18
APPENDIX A	20
APPENDIX B	26

FIGURES

No.		
1.	Diagram showing the Area of Influence Concept	4
2.	Plan of Refinery Area showing Subsidence Observation Lines, undermined at Nordstern Colliery	7
3.	Progressive Subsidence Development monitored along Observation Line 12, Nordstern Colliery, 1969-82	8

Page

4. Plan showing Panel Layout used in Appendix A for Data Input to Modified Bals Subsidence Prediction Model 10
5. Projected Subsidence Map for the Nordstern Colliery Refinery Area, 1970-80 11
6. Longitudinal (Dynamic) Profiles for a Series of Face Advance Rates 12

INTRODUCTION

In April 1983, a discussion document (1) was circulated within CANMET and interested outside parties concerning the conception and implementation of a long term subsidence research programme for the Sydney Coalfield, Nova Scotia. The need for such a programme stems from a discrepancy which exists between North American and United Kingdom guidelines for the safe working of undersea coal mines (2),(3). The discrepancy arises between the values of 8.75 mm/m (N. American) and 10 mm/m (U.K.) tensile strain which can be induced at seabed before the risk of water ingress to the mine workings is deemed unacceptable.

Existing U.K. guidelines (3) have been found unreliable, in that more than 15 mm/m of tensile strain can be induced at the base of heavily water bearing Permian strata overlying the mine workings without the ingress of water. Alternatively, water has also been experienced in mine workings where the estimated tensile strain was less than 10 mm/m at the base of the Permian (4). It would therefore appear that the existing guidelines require 'fine tuning' so as to take into account different geological and mining conditions.

With respect to subsidence criteria, it is important to realize that the values of tensile strain in both guidelines (2), (3) are based on the predictive methods outlined in the National Coal Board (NCB) Subsidence Engineers Handbook (SEH) (5), which itself was empirically derived from U.K. land based data. The SEH is known to have its limitations in the U.K. particularly in those areas where few of the cases were collected or complex geological environments exist. It is also well known that the SEH cannot be used with any success in North America, particularly in the Appalachian Coalfield. The U.S. Bureau of Mines is currently undertaking an extensive mining subsidence data collection programme from which it is expected an empirical predictive method may eventually be derived. In West Germany, a mathematical prediction technique known as the 'sphere of influence' method is used to predict mining subsidence, although certain of the parameters require empirical calibration. This has been achieved over the past 40 years and it is interesting to note that the data set is continually being up-dated as mining conditions change.

It is therefore essential that any subsidence prediction model used in the Sydney Coalfield must be both applicable to the prevailing conditions and sufficiently accurate to enable safe guidelines for undersea mining to be confidently drawn up. These features are particularly important since an overly stringent guideline can result in the sterilization of economically significant coal reserves and the adoption of a less than efficient mine design. Alternatively, a guideline which is too lax could result in the access of water to the mine workings, lost production and increased costs.

In November 1983, a visit was made to West Germany and the United Kingdom in order to discuss and assess the current status of subsidence research in both countries. In this manner, existing information and ideas were exchanged, but more importantly a direct appreciation of the problems encountered by other researchers was obtained. The object of the visit was therefore twofold:

1. Determine the current status of subsidence research in both countries and assess its potential application to the programme being established for the Sydney Coalfield.
2. By determining at first hand what has already been achieved, it is possible from the outset of the CBCRL programme to avoid the unnecessary duplication of existing work and also the pitfalls and problems already encountered by others.

This report is therefore intended to present the current status of subsidence research in both West Germany and the U.K. and discuss those features considered relevant to the programme currently being undertaken in the Sydney Coalfield.

SUBSIDENCE RESEARCH IN THE RUHR COALFIELD, WEST GERMANY

Introduction

Two main coal producing areas exist within West Germany:

1. The Ruhr
2. The Saar

A visit was made to Steinkohlenbergbauverein, Essen which is situated in the Ruhr Coalfield. Discusssions therefore centered around subsidence research in the Ruhr Coalfield, although it should be noted that similar research is also being done in the Saar Coalfield.

The inclined seams of the Ruhr outcrop at surface, although a significant portion of the coalfield is unconformably overlain by a thick cover of Triassic and Cretaceous deposits, some horizons of which are water bearing. To date, no significant problems have been experienced with water ingress from aquifer horizons, although serious problems have been encountered with water inrushes from old or abandoned mine workings. An average figure quoted for the Ruhr area is 30 m^3 of water pumped from existing and abandoned workings for every 1 m^3 of coal produced.

Subsidence Prediction

Subsidence prediction is undertaken using the Bals method, which was originally formulated during the 1930's and is based on a 'sphere of influence' concept. The concept proposes that for a given point P on the surface, the area of influence in a level seam is a circle which is the base of an imaginary cone whose axis passes vertically through the overlying strata and has P at its apex (Figure 1). The diameter of the area of influence is equal to 1.4 times the depth of the seam. Workings outside the area cannot cause subsidence to the point P, whilst all workings within the area must have an effect on it and contribute to its subsidence. It also follows that all the coal within the area of influence must be extracted for the point P to undergo maximum subsidence. If only part of the area is worked, then the point P will only subside a fraction of the maximum possible amount (6).

Subsidence Monitoring in the Ruhr Coalfield

In order to monitor subsidence over the industrial Ruhr, a regional survey network has been established across the area. The network base line is located well away from the Ruhr in the vicinity of Munster (it being assumed that this area undergoes zero subsidence). Regional survey stations are positioned on a 10 km grid and it takes approximately 2 years to complete and update a survey. However, because of the lag between surveying and updating,

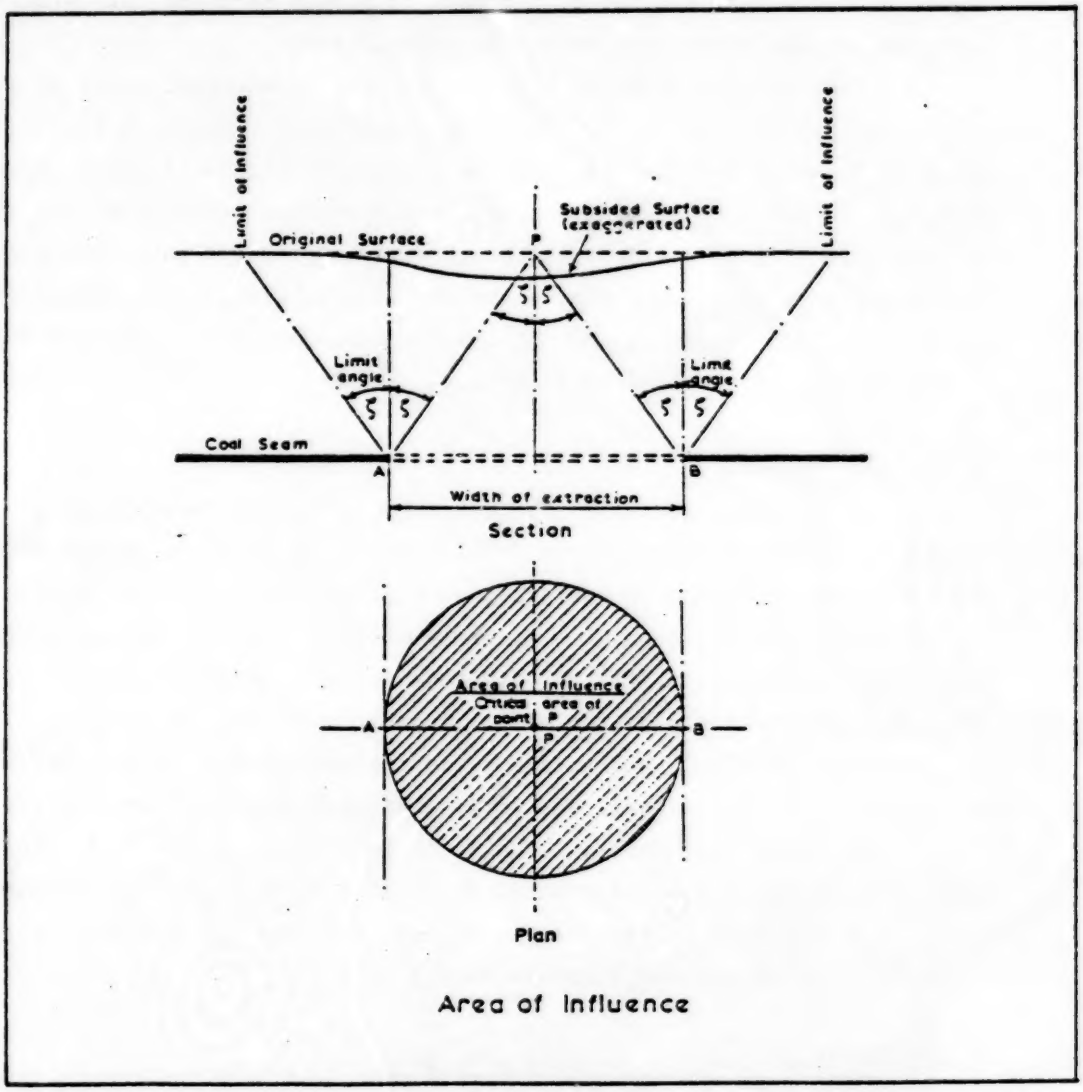


Figure 1 - Diagram showing the Area of Influence Concept (after Shadbolt (6))

a complex series of mathematical corrections are done to 'time correct' the data and produce results for the coalfield under static conditions.

Survey networks established to monitor localized subsidence are tied to a local network which in turn can be integrated into the regional system. Subsidence within a localized area is monitored using survey stations spaced on 25 - 50 m centres or one-eighth seam depth.

Subsidence prediction is undertaken using the Bals theory in a form which has been modified for EDP (Electronic Data Processing). The original programme was developed by Ehrhardt and Saurer (7) in 1961 and requires the input of 4 or more panel points (geodetic coordinates), seam thickness and the seam depth. Additional model parameters have been derived empirically from field observations collected over a 50 year period. New data is continually being integrated into the model so that updated parameters become available as mining conditions change. Vertical and horizontal displacement, strain or curvature can all be calculated for any given section across a longwall panel.

The model is used to construct 'subsidence' maps for the Ruhr area on a 1 to 25 year mining cycle and these in turn can easily be updated as circumstances change. A 5 year plan for the Ruhr requires approximately 12,000 subsidence profiles and 4 days of computer time. The resultant profiles have an accuracy of 2 - 3% assuming the input data is correct.

The coalfield has few problems due to the presence of water bearing strata. However, an extensive system of inland canals and locks do exist across the industrial Ruhr. Although land based surveys are carried out along the banks of the waterways, it is interesting to note that the waterway regulatory body carries out continuous sonar-depth monitoring programmes to determine the amount of settlement due to mining. The survey accurately measures the depth of water between the boat and the bottom of the canal. The data is then used to either collaborate or dispute data collected from the adjacent land based stations.

Recently, subsidence monitoring has been undertaken using aerial photographic techniques, which can give a resolution of greater than ± 5 cm in the vertical plane. However, even though a complete survey from initial filming to final data processing can be done in less than two days, some

concern has still been expressed over the validity of the technique for subsidence research. Additional problems, such as adverse weather conditions and atmospheric pollution can render ground stations invisible from the air for days or even weeks on end. It is therefore interesting to speculate whether aerial survey techniques will ever replace land based methods, even though some problems do exist.

Finally, a detailed examination of observed subsidence profiles for the Ruhr Coalfield has revelaed that significant variations do occur with changes in geology. Empirical techniques have therefore been used to quantify these variations and integrate the results into the overall prediction model.

A Case Study - Nordstern Colliery

At Nordstern Colliery, a total of 10 seams have been worked at depths between 250 and 1000 m, with seams thicknesses varying between 0.8 and 2.5 m.

One section of the colliery workings lies beneath a major oil refinery which covers a surface area of approximately 7.2 km^2. In addition to the refinery complex, the site contains a variety of storage tanks and over 500 km of pipework, some of which is pressurized to over 200 bars (2800 psi). Figure 2 shows a plan of the refinery area along with the subsidence observation lines.

During the past 40 years, a total of 6 seams have been mined beneath the refinery, which has lowered the site by a total vertical height of 8 m. To prevent damage, a guideline of 5 mm/m tensile strain was formulated for the area and observation lines established across the site in order to monitor the actual subsidence on a regular basis. Figure 3 shows progressive subsidence development across Observation Line 12, (Figure 2) for the period 1969 to 1982. To date, only 2 mm/m tensile and 6 mm/m compressive strain has been permanently induced across the site. This has been achieved by using carefully controlled mine layouts and mining methods (using total extraction and stowing techniques).

When designing the mine layout, it was assumed that the overlaying strata only breaks to 3 times the seam height, after which point it begins to bend. Similarly, in the case where new workings were planned for areas in

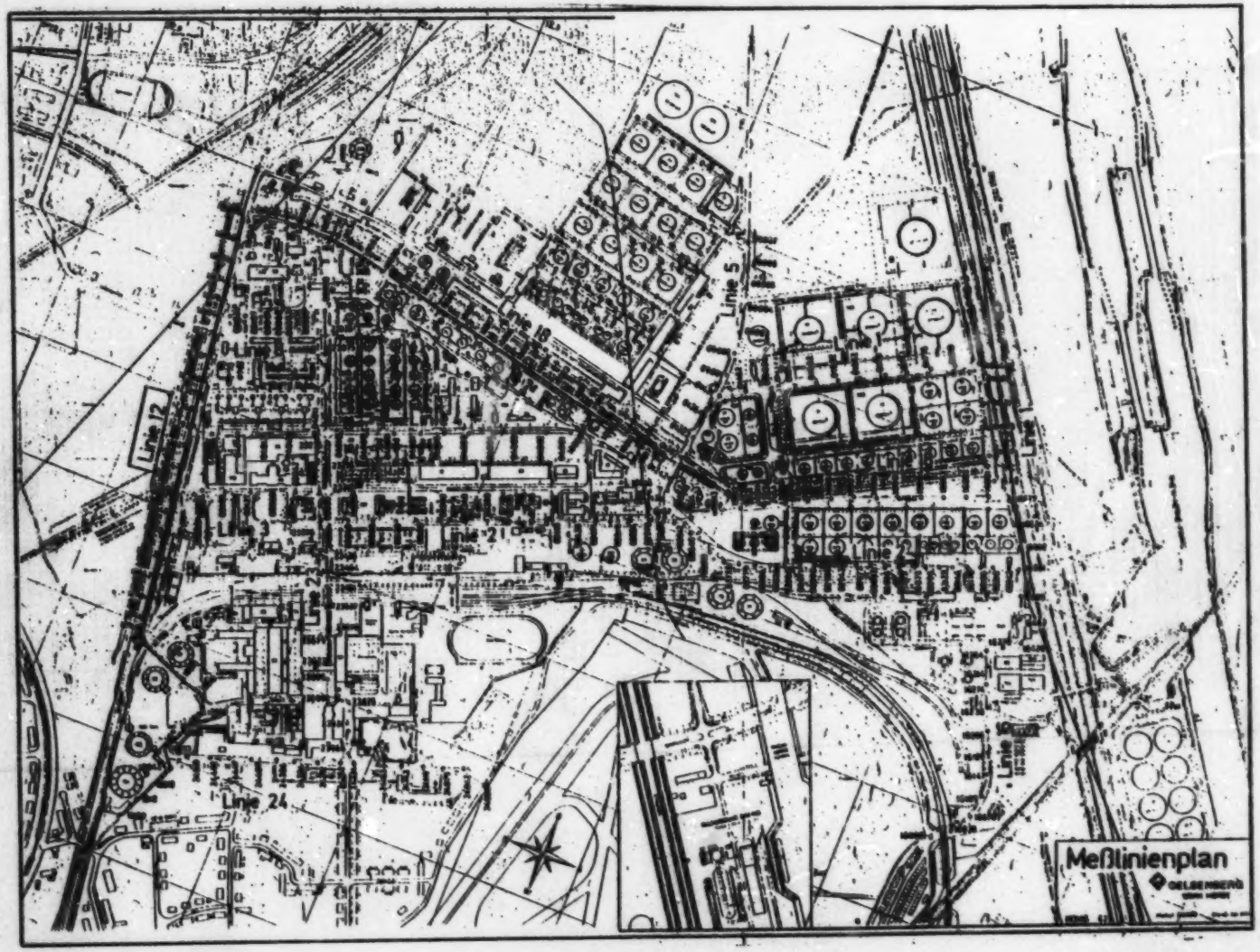


Figure 2 - Plan of Refinery Area showing Subsidence Observation Lines, Undermined at Nordstern Colliery

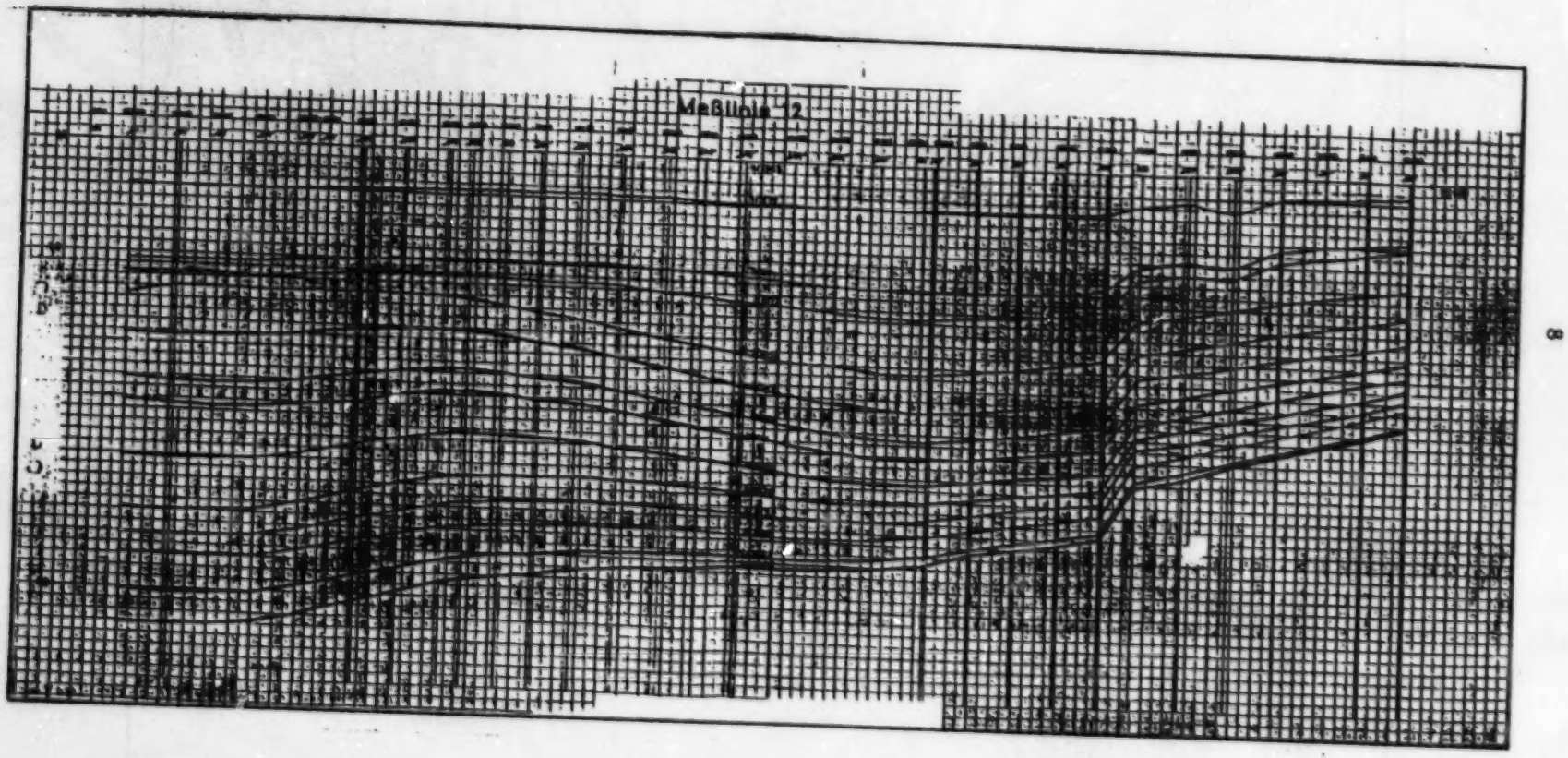


Figure 3 - Progressive Subsidence Development monitored along Observation Line 12, Nordstern Colliery, 1969-82

which the underlying seams had already been worked, it was assumed that all ground movement and surface settlement had ceased after a period of 5 years.

In the industrial area around Dortmund, it is assumed that up to 8 mm/m of tensile strain can be induced before surface damage becomes significant.

Subsidence Prediction - Ruhrkohle AG

A visit was made to Ruhrkohle AG to discuss the practical application of the modified Bals subsidence prediction model. A variety of data input format sheets were examined with respect to a given case history, although unfortunately the trial data set was not run on the model. Figure 4 shows the panel used as an example and Appendix A the computer input format sheets.

Subsequently, a series of subsidence maps for the Ruhr showing 1 to 25 year mining cycles were seen. Figure 5 shows a subsidence map for the period 1970 to 1980 for the Nordstern refinery area.

Finally, the rate of subsidence trough development with respect to face advance was discussed. Figure 6 shows a longitudinal (dynamic) profile for a series of face advance rates varying from 2 m/day to 15 m/day. It is immediately apparent that the greater the face advance rate, the greater the induced strain and likelihood of fissuring at surface.

SUBSIDENCE RESEARCH IN GREAT BRITAIN

The visit to Great Britain can be divided into three parts:

1. NCB North-East Area HQ, Gateshead,
2. NCB Mining Department HQ, Doncaster,
3. Nottingham University, Mining Department.

1. NCB North-East Area HQ, Gateshead

Extensive work has already been undertaken by the author in this area and the main purpose of the visit was to obtain an update on events since 1982. Previous work by the author can be found elsewhere (4), (8).

No significant events have been recorded in the area since 1982. However, in the light of the recent experience at Wistow Colliery, Selby,

Figure 4 - Plan showing Panel Layout used in Appendix A for Data Input to Modified Bals Subsidence Prediction Model

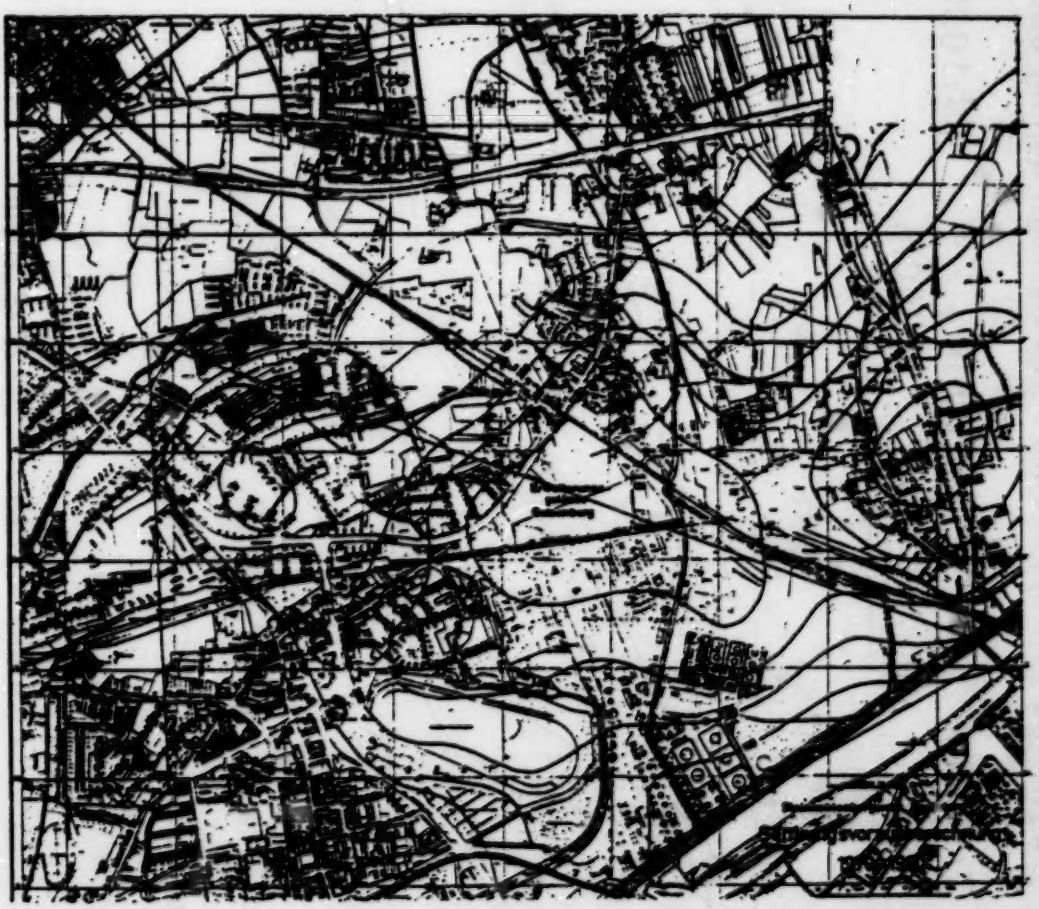
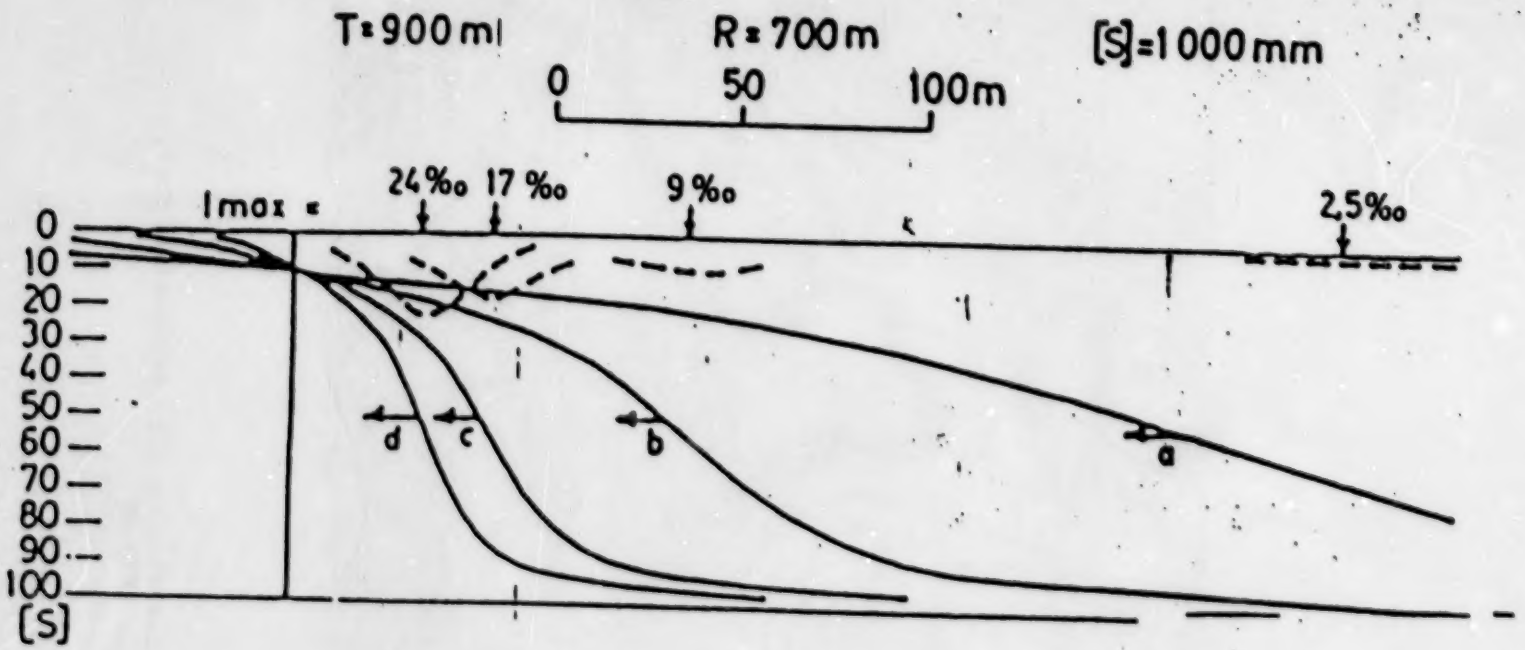


Figure 5 - Projected Subsidence Map for the Nordstern Colliery Refinery Area, 1970-80

Dynamic effects from relatively high mining speeds



mining speed		R extracted after
a)	2m/d = 0.06 R/ month	16.7 months
b)	5m/d = 0.15 R/ month	6.6 months
c)	10m/d = 0.3 R/ month	3.3 months
d)	15m/d = 0.45 R/ month	2.22 months

Figure 6 - Longitudinal (Dynamic) Profiles for a Series of Face Advance Rates (after Pflaging, Appendix B, No. 1)

6 mm/m (single seam) and 12 mm/m (multi-seam) tensile strain contours at the base of the Permian strata are now required on all mine plans.

At Horden Colliery, Durham extraction in the uppermost seam (High Main) is undertaken using Herring Bone room and pillar. The rooms are located on 20 m centres with 14 m pillars, which results in a 40% extraction ratio. The last longwall in the High Main, E81 (100 m faceline, 1.52 m extraction, Z-retreat working and 125 m of cover to the base of Permian) had to be abandoned when a water feeder with a yield of 2.9 m^3/min (650 gpm) was encountered. The feeder yield subsequently reduced to 1.82 m^3/min (400 gpm).

At Easington Colliery, which is adjacent the Horden workings, 6.7 m^3/min (1475 gpm) are pumped from the mine and again yielded principally from the High Main seam workings. A complex geological structure which occurs along the North-East coast results in the formation of 'dome' structures. A 'dome' has been encountered in the colliery workings and it is expected that water will shortly be encountered in the Low Main seam workings, where the cover to the base of the Permian, on the flanks, reduces to below 122 m.

In Northumberland, the only remaining coastal colliery is the Lynemouth/Ellington complex. Here, room and pillar extraction is undertaken in the Brass Thill seam with 5.8 m rooms and 2.13 m extraction in a 2.51 m seam. JCM Series 12 continuous miners are used and the shale roof is supported by 'props and bars'. An exemption to the 1968 PI (3) was granted in order to work in the Brass Thill seam.

No significant events have been recorded at the Dawdon and Westoe Collieries since 1982.

2. NCB Mining Department HQ, Doncaster

The NCB Subsidence Engineers Handbook (5), while valuable for predicting subsidence in those areas where the original was collected, does not fulfill the universal role of predicting subsidence in all areas of the U.K. At present, some field data is being collected, principally in those areas of special significance, such as Selby, and it is expected that this will eventually be incorporated into the original data set.

A detailed examination of the original SEH data set reveals the existance of certain anomalous points, which in the process of compilation

were either ignored or smoothed. However, a careful study has revealed that these points can be related to specific mining conditions or geological features. Similarly, a detailed analysis of subsidence data from the East Midlands Coalfield has shown a distinct regional trend different to that of the national values. It is therefore interesting to speculate on whether regional trends also exist for each of the principal coalfields in Great Britain. However, current work is being restricted to a detailed re-evaluation of the existing data and it is expected that a supplement to the current handbook may be issued in due course.

With regard to the effects of mining subsidence on surface structures, it was suggested that a more useful concept might be 'the total displacement of a point within the trough' rather than the normally accepted parameters of vertical displacement and strain. The introduction of this concept would involve a comprehensive re-evaluation of the SEH data set, which is deemed impractical. However, if the data set were only just being established, then its inclusion and significance should be given very careful consideration.

A computerized model of the SEH, known as 'SPAN' is currently being developed at the NCB Operational Research Unit in Harrow, U.K.

At present, the NCB is establishing a committee to review the 1968 PI Guidelines for Undersea Mining (3), with respect to the following points:

1. The minimum value of 105 m of cover between the mining horizon and the base of the major aquifer need not be changed.
2. The current 10 mm/m tensile strain value is not necessarily correct for all mining conditions.
3. An alternative parameter, such as curvature rather than tensile strain, might be more useful for determining the safety of undersea mine workings.

3. Nottingham University, Mining Department

Current research activity is focused on the development of computer models for subsidence prediction. At present, the Department has almost completed a sophisticated model of the SEH, which allows 2 and 3 dimensional profiles to be plotted along any section of the subsidence trough. It is interesting to note that this model is similar to that currently being developed by the NCB.

THE EFFECTIVE SEALING OF OFFSHORE EXPLORATION BOREHOLES

In West Germany, coal pillars up to 60 m in diameter are left around surface exploration boreholes. Prior to backfilling with cement, the boreholes are surveyed in order to accurately determine their location within the proposed mine workings. Occasionally, the borehole pillars are mined and to date no adverse effects have been reported.

In the United Kingdom, offshore boreholes in the North-East Area have a coal pillar up to 200 m in diameter left around them. Although backfilled with cement, they are seldom surveyed in order to accurately locate there intersection with the mining horizon.

Exploration boreholes therefore sterilize economic amounts of coal with their surrounding pillar and therefore significantly influence the final mine design. Alternatively, the mine design can be produced first and the optimum positions for the boreholes determined. A conflict therefore arises between the need for accurate geological information at the mining horizon and an optimum mine design. If a highly effective sealing technique could be developed, the coal pillar could be mined and the conflict resolved.

IN SITU STRATA PERMEABILITY CHANGES DUE TO MINING

A detailed understanding of in situ strata permeability changes induced by longwall mining would help solve the following problems:

1. Development of effective guidelines for undersea mining, with respect to the minimum amount of cover required and the maximum tensile strain that can be induced at seabed.
2. The effectiveness of sealants used in offshore boreholes.
3. An understanding of the mechanism by which water enters longwall panels and the development of effective counter measures.

No work of this nature has been undertaken in West Germany. In Great Britain, some monitoring of in situ permeability changes around longwall workings has been undertaken by Notthingham University in conjunction with the NCB (8), (9).

DISCUSSION

Unfortunately, the NCB SEH (5) is not a universal method for predicting subsidence anywhere in the world. Limitations exist regarding its use in some U.K. areas and to date its application to European, North American and Australian conditions has been far from successful. However, it is a particularly useful tool, not only in those U.K. areas where the original data was collected, but more importantly as a means of deriving a first order approximation of subsidence in any coalfield with conditions similar to those found in the U.K. Its direct and unquestioned application to the Sydney Coalfield should therefore be treated with caution.

Four main points concerning subsidence prediction techniques in West Germany and Great Britain are considered particularly relevant to the current Sydney Coalfield programme:

1. Although different prediction techniques have been adopted in each country, both techniques require either calibration with or an input of field data. Any model/technique adopted for the Sydney Coalfield will therefore require verification with field data.
2. Both countries recognize that geological conditions can significantly influence the final subsidence profile. Considerable work has therefore been undertaken using both field programmes and the analysis of existing data to quantify geological effects and integrate them into the existing prediction methods. However, it should be noted that although localized geological conditions do exist within the Sydney Coalfield, they cannot be directly compared with the regional trends seen within West Germany and Great Britain.
3. Both countries recognize that computer applications and techniques are playing an increasingly important role in subsidence analysis and prediction. Any model/technique adopted for the Sydney Coalfield should therefore be developed for EDP.

4. Although tensile strain is generally recognized as the limiting parameter for determining the safety of undersea coalfield workings, it was suggested in Great Britain that an alternative parameter such as curvature might be more effective. To date, little work has been undertaken to verify this concept and its applicability to the Sydney Coalfield should be given careful consideration.

With regard to the effective sealing of offshore/surface exploration boreholes, both countries recognize that the surrounding coal pillars sterilize economic amounts of coal and significantly influence the final mine design. However, neither country has undertaken any research in this area and none is envisaged. Similarly, with respect to understanding the mechanisms associated with in situ permeability, only Great Britain has undertaken any research to date. A better understanding of these mechanisms would certainly allow more effective guidelines to be formulated, rather than simply relying on criteria obtained from 'surface' observations. The effective sealing of offshore boreholes and a better understanding of in situ permeability changes should therefore be considered an integral part of any long term subsidence research programme initiated within the Sydney Coalfield.

CONCLUSION

In West Germany and Great Britain experience has shown that effective subsidence prediction techniques can be developed provided sufficient field data is available. Similarly, subsidence engineering and mine planning can be successfully integrated to allow maximum coal extraction below even the most sensitive surface areas.

Finally, to develop an efficient prediction technique for the Sydney Coalfield, two interrelated fields of research should be pursued:

1. The development of empirical/mathematical techniques, verified by field data.
2. The determination of in situ strata movements/permeability changes associated with longwall workings.

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to the large number of people who freely gave their time and unique experience to this particular field of interest. In particular, thanks are due to Herr Kaulfuss, Herr Wagner, Subsidence Section and Herr Kampling, Interpretation Section, Steinkohlenbergbauverein, Essen; Dr. Ing Mehrhoff, BWD Nordstern and Dr. Pflanging, Ruhrkohle AG; Mr. J. Teare, Area Surveyor and personnel of the Subsidence and Geological Sections, NCB North-East Area HQ; Mr. C. Shadbolt, HQ Chief Subsidence Engineer and Mr. S. Newson HQ Strata Control Engineer, Doncaster; Professor T. Atkinson, Dr. B.N. Whittaker and Dr. R.N. Singh, Department of Mining Engineering, University of Nottingham. Mention must also be made of the documents provided which will be of considerable interest and assistance, Appendix B.

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APPENDIX A

RAG

Bodenbewegungsvorausberechnung

3. Flächenbezeichnungen

Datum:
Name:

Blatt :

Programm-kennzeichng.	KA	Gesellschaft Anlage	Flächen-Nr.	Flöz	Betriebsbezeichnung
1 2 3 4 5 6	8 9	11 12	13 14 15 16 17 18	19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51	
FMS000	10	341		12ZOLLVEREIN 2	

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Bodenbewegungsvorausberechnung

7. Flächeneckpunktszuordnung

Datum:

Name:

Blatt:

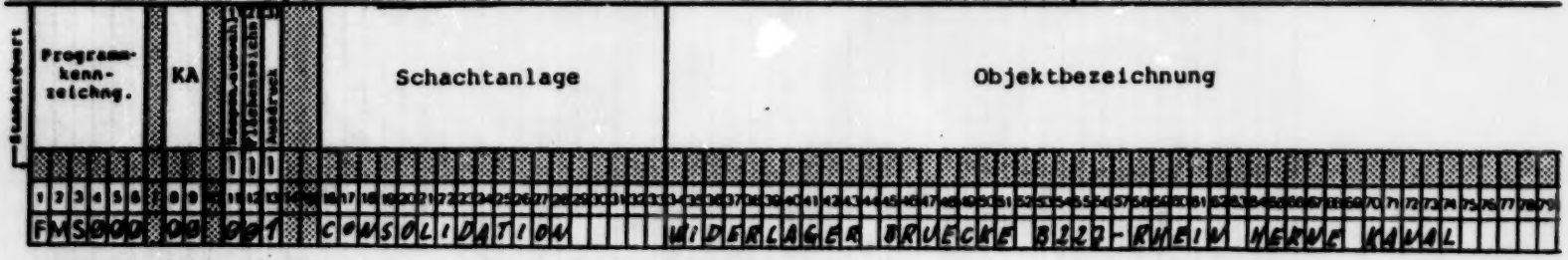
Programm-kenn-zeichng.	KA	Gesellschaft Anlage	Flächen-Nr.	Mächtigkeit (m)	Absenkungs-faktor (%)	Seit-faktor (%)	Flächeneckpunkt - Nr.									
							1	2	3	4	5	6	7	8	9	10
1 2 3 4 5 6	8 9	11 12	14 15 16 17 18	20 21 22	24 25	27 28	30 31 32	34 35 36	38 39 40	42 43 44	46 47 48	50 51 52	54 55 56	58 59 60	62 63 64	66 67 68
F M S	6 0	3 4 1	1 2	1 4 5	1 0 0	1 0 0	1	2	3	4	5	6				

A 21

Bodenbewegungsvorausberechnung

1. Steuerungs- und Textangaben

Datum: Blatt:
Name:



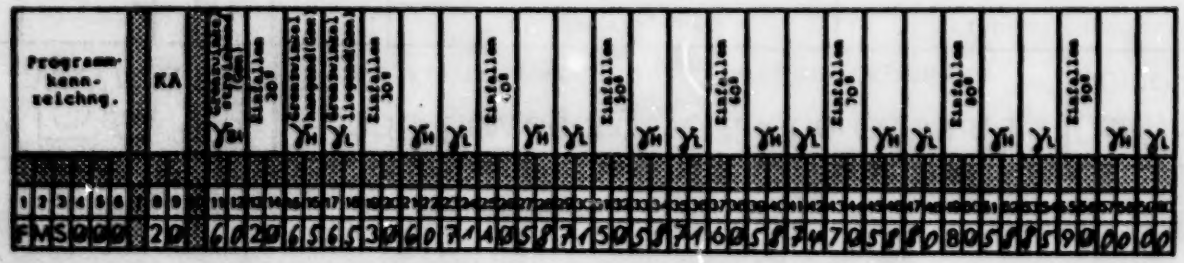
1) Komponentenauswahl
   Ø - alle Komponenten
   1 - nur Senkungen

2) Flächen zeichnen
   Ø - Flächenumrisse drucken
   1 - Flächenumrisse nicht drucken
   2 - Flächenumrisse drucken, keine Berechnung

3) Ausdruck
   Ø - Einzel- und Summenformula
   1 - nur Summenformular

A 22

2. Grenzwinkel


Programm-kenn-zeichng.
KA
Einfallen 20°
Einfallen 30°
Einfallen 40°
Einfallen 50°
Einfallen 60°
Einfallen 70°
Einfallen 80°
Einfallen 90°
FMS000 20 60 20 65 65 30 60 71 40 55 71 50 55 71 60 55 71 70 55 71 80 55 71 90 60 60

RAG

Bodenbewegungsvorausberechnung

4. Koordinaten der Flächeneckpunkte

Datum:

Name:

Blatt:

Programm-kennzeichng.	KA	Gesellschaft Anlage	Flächen-Nr.	Flächeneckpunkt				Flächeneckpunkt			
				Pkt.-Nr.	Rechtswert (m)	Hochwert (m)	Höhe (m) ±	Pkt.-Nr.	Rechtswert (m)	Hochwert (m)	Höhe (m) ±
FMS	11	3441	12	1	2575658357121844	5714	850	2	2575707045571309	5711	860
		3441		3	7739447	133315	580	4	7751516	13162	730
		3441		5	7211727	1293131	710	6	7664727	12655	700

A 23

RAG

Bodenbewegungsvorausberechnung

5. Berechnungspunkte (Einzeln)

Datum :

Name :

Blatt :

Programm-kenn-zeichng.	KA	Punkt-Nr.	Rechts-wert (m)	Hoch-wert (m)	Höhe (m) ±	Phi (Gon)
1 2 3 4 5 6	8 9	10 11 12 13 14 15 16 17 18	19 20 21 22 23 24 25 26 27	28 29 30 31 32 33 34 35 36	37 38 39 40 41 42 43 44 45	46 47 48 49 50
F M S 0 0 0	4 0	1	2 5 7 6 6 8 6	5 7 1 3 1 4 5	+ 4 5	1 9 0
		2	7 6 6 9 6	1 3 0 9 7	+	
		3	7 6 7 2 2	1 3 1 5 0	+	
		4	7 6 7 3 2	1 3 0 9 6	+	

A 24

BAG LIPPE	EINGABEFORMULAR ZUR STANDARD-WERTLINIENDARSTELLUNG AUS BBVB-DATEIEN	BLATT	
		DATUM	

F M S 0 2 1 10

SPALTE 10 + 11 = KOMPONENTENBEZEICHNUNG

10 = SENKUNG CM ,11 = SCHIEFLAGE PHI 1 MM/M ;12 = SCHIEFLAGE PHI 2 MM/M ,13 = KRÜMMUNG PHI 1 KM
14 = KRÜMMUNG PHI 2 KM ,15 = VERSCHIEBUNG PHI 1 CM ;16 = VERSCHIEBUNG PHI 2 CM ,17 = LÄNGENÄND. PHI 1 MM/M
18 = LÄNGENÄND. PHI 2 MM/M ,21 = SCHIEFLAGE GESAMT MM/M ;25 = VERSCHIEBUNG GESAMT CM ;

F M W 0 0 0 20 1

	AUSGANGSPUNKT (LINKE UNTERE ECKE) RECHTS (M)	HOCH (M)	AUSDEHNUNG RECHTS (M)	HOCH (M)
F V Z 1 0 4 10	2576000	0057120000	2000000	2000000
F V Z 1 0 4 20	5000			

MASSTAB 1:

	LINIENART	LINIENABSTAND	STRICHSL. (MM)	LINIENTYP	BESCHRIFTG.	FORMAT TYP E	FORMAT NACHK.-STELLE
F M W 0 0 0 30	1	10	0	3	1	1	
F M W 0 0 0 30	2	100	0	6	1	1	
F M W 0 0 0 30							

1) = LINIENART LINIENABSTAND
1 — 5
2 — 10
3 — 50

2) = LINIENTYP
1 ———
2 ....
3 — · — · —
4 . . . . . .
5 — — — —

3) = BESCHRIFTUNG
1 = JA
2 = NEIN

4) = FORMATTYP
I = GANZE ZAHL
F = DEZIMAL-BRUCHZAHL

0 — 5 — 10 — 15 — 20 — 50

EMPFÄNGER #

F V Z 0 5 0 30 1

AABI.TS.2

A 25

APPENDIX B

List of documents supplied during November 1983 visit to Steinkohlenbergbauverein, Essen, West Germany, NCB North-East Area, HQ, Gateshead, U.K. and NCB HQ Mining Department, Doncaster U.K.

1. Pflaging, K., "Messen und Berechnen der Einwirkungen des Steinkohlenbergbaus auf die Tagesober flache als Mittel der Bergschadenprophylaxe"; Das Markscheidewesen, 88(1981) Nr. 2.

2. Pflaging, K., "Zur Asymmetrie von Senkingsmulden und ihren dynamisehen Zwischenformen bei relativ hoher Abbaugeschwindigkeiten"; (-)

3. Pflaging, K., "Aktualisierung der mathematischen Ansatze fur allgemeingultige Vorausberechnungsverfahren"; Bundesministerium fur Forschung und Technologie, Bergbau Forschung GmbH, Essen, Ruhrkohle AG, Essen, Marz, 1983.

4. Mines (Precautions Against Inrushes) Regulations 1979, Health and Safety, Mines and Quarries Statutory Instruments, 1979, No. 318.

5. Shadbolt, C.H., "Mining subsidence - historical review and state of the art"; NCB Subsidence Engineering Section.